Utilization of Mahogany Leaf Waste as Pulp for Papermaking

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***Abstract*—The demand for pulp as raw material for various products has been increasing in recent years. Since 1998, material sources derived from wood have dominated the world's total pulp production. Many researchers are looking for non-wood pulp raw materials to reduce global warming. This research aimed to find an alternative non-wood pulp raw material by utilizing mahogany leaf waste. Delignification of mahogany leaf was conducted chemically using NaOH solution with a solid-to-liquid ratio of 1:10. Mahogany leaf with the size of 0.25–0.42 mm was cooked at a temperature of 80 °C for 120 and 140 min. Pulp processed using 20% NaOH with a cooking time of 120 min has the highest alpha cellulose content (59.17%). Pulp processed using 10% NaOH with a cooking time of 120 min has the lowest lignin content (15.81%). Pulp for papermaking must contain more than 40% alpha cellulose content and less than 25% lignin content. Therefore, this research proved that mahogany leaf waste can be used as an alternative non-wood pulp raw material for papermaking.**

Keywords—mahogany leaf waste; pulp; NaOH; alpha cellulose; lignin

I. INTRODUCTION

The ever-increasing global pulp demand has been exhausting wood supply at such an alarming rate. From 1970 to the present, the non-wood plant fiber pulping capacity has increased on a global basis two to three times as fast as the wood plant fiber pulping capacity [1]. This phenomenon is inevitable because wood is still the main source of pulp [2]. However, this situation is dire. Thus, finding alternative pulp raw materials is highly urgent for the following reasons: (1) not all countries have dense forests, (2) global warming and climate change, and (3) paper production using pulp as raw material is highly consumptive of energy. However, the search for an alternative source is a rather difficult task. Different sources will yield different qualities of pulp. The two main requirements for pulp to be viable for papermaking are more than 20% alpha cellulose content and less than 25% lignin content [3]. Considerable research has been conducted in Indonesia to propose alternative sources of pulp, such as banana midrib [4], banana stem [5], hollow cluster of palm trees [6], and cogon grass [7]. Mahogany has been an economically important timber species in the Neotropics for more than three centuries; it has a large population and is globally abundant [8]. This research aimed to test the feasibility of mahogany leaf waste as an alternative source of pulp for papermaking.

II. MATERIALS AND METHODS

This experiment started with the preparation of mahogany leaf waste. The mahogany leaf waste was dried and reduced in size to approximately 0.25–0.42 mm. Then, the lignocellulose composition of the material is analyzed on the basis of the SNI 0444:2009 and SNI 0492:2008 standards. After the mahogany leaf waste was dimensionally reduced, specimens weighing 80 g were obtained and cooked using 800 mL of NaOH with the concentrations of 10%, 15%, and 20%. This process was done under a temperature of 80 °C for 120 and 140 min. The produced pulp was filtered and washed using distilled water and 2% HCl until it was thoroughly cleaned. Subsequently, the pulp was completely dried using an oven. Finally, the test was initiated after the pulp was taken out of the oven. SNI 0444:2009 is the standard used to determine the alpha cellulose level, and SNI 0494:2008 is the standard used to determine the lignin level. The flowchart of the experiment is presented in Fig. 1.

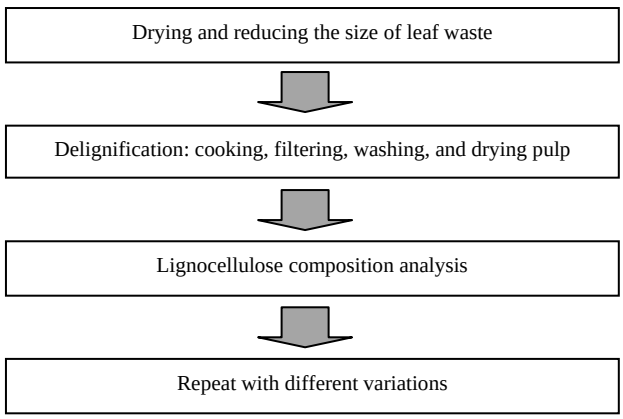

Fig. 1. Flowchart of the experiment

III. Results and Discussion

The lignocellulose composition analysis showed that mahogany leaf contains 23.49% alpha cellulose, 2.65% beta cellulose, 4.57% gamma cellulose, and 41.17% lignin. The details of the chemical composition and the test results of mahogany leaf are shown in Table 1.

TABLE 1 Lignocellulose composition analysis results of mahogany leaf

Time (min)	**NaOH concentration (%)**	**Parameter**		
		Alpha cellulose (%)	*Kappa number (KN)*	*Lignin (%)*
120	10	48.24	121.63	15.81
	15	46.87	126.38	16.43
	20	59.17	142.54	18.53
140	10	49.89	146.12	19.00
	15	41.60	122.71	15.95
	20	58.48	134.69	17.51

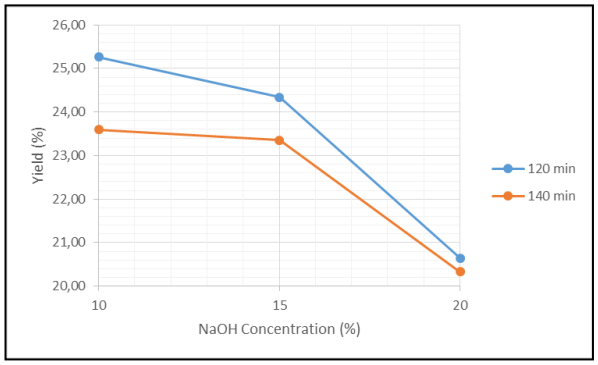

Fig. 2. Effect of NaOH concentration on pulp yield

A. *Effect of NaOH concentration on alpha cellulose and lignin pulp yields*

At a cooking time of 120 min, the alpha cellulose content in pulp increases from 23.49% to 48.24% after delignification using 10% NaOH. By contrast, the lignin content decreases from 41.17% to 15.81%. Meanwhile, after delignification using 20% NaOH, the alpha cellulose content increases to 59.17% and the lignin content decreases to 18.53%. These results show that the increase in alpha cellulose content leads to the increase in lignin and hemicellulose contents. The pulp yields different results when different NaOH concentrations are used: (1) 10% NaOH, 25.26%; (2) 15% NaOH, 24.34%; and (3) 20% NaOH, 20.65%. Fig. 2 shows the effect of NaOH concentration on pulp yield.

The concentration of the cooking solution affects the possibility of contact between the raw material and the cooking solution. The higher the NaOH concentration in the cooking solution is, the higher the possibility of contact between NaOH and raw material. The bonds in lignocellulose break, which changes the pore structure, microstructure, macrostructure, chemical composition, and lignocellulose crystallinity [9]. The reaction between NaOH and lignin causes the lignin molecule to degrade because of the breaking of the aryl–ether, carbon–carbon, aryl–aryl, and alkyl–alkyl bonds. Fig. 3 shows the degradation and breakage of the aryl–ether bond by the OH compound from the NaOH solution. Thus, lignocellulose is separated into lignin and cellulose. The thick black color of the cooking solution indicates the presence of black liquor. The amount of degraded organic matter ensures that the alpha cellulose produced has a pure composition. However, the yield of pulp produced is low.

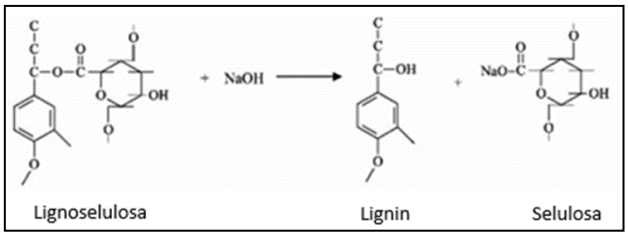

Fig. 3. Lignocellulose degradation mechanism of NaOH

B. *Effect of cooking time on alpha cellulose and lignin pulp yields*

The data in Table 1 show the effect of cooking time, i.e., 120 and 140 min, on the yield. A longer cooking time causes the alpha cellulose pulp yield to decrease. The cooking time affects the chemical composition and yield of pulp produced. Operating temperatures below 140 °C increases the rate of reaction, so that the cooking time required increases. The longer the cooking time is, the higher the cellulose content, the lower the lignin content, and the lower the pulp yield. However, a longer cooking time can cause the degradation of lignin to form the product again. Cellulose that has been separated can also be degraded, so that the cellulose content and pulp production decrease and the lignin content increases. This result is certainly undesirable because the main purpose of delignification is to obtain the highest cellulose content by degrading lignin from raw materials. Particularly for the 10% NaOH concentration, the alpha cellulose level increases from 48.24% (120 min) to 49.89% (140 min) because the NaOH concentration and cooking temperature

are low. Thus, the time needed for the delignification process is longer.

In a previous study, Surest et al. [10] made pulp from roselle stem using different concentrations of NaOH cooking solution with a cooking time of 60 min. They obtained 58% pulp yield at 5% NaOH concentration, 55% pulp yield at 10% NaOH concentration, 53% pulp yield at 15% NaOH concentration, and 50% pulp yield at 20% NaOH concentration. The comparison of the data in Table 1 and the results of Surest et al. [10] shows that, within the time span of 120 and 140 min, the effect of cooking time on the reduction in pulp yield did not produce significant changes. This finding will certainly have an effect on the energy consumption and economical feasibility of the production process.

IV. Conclusions

Research on the use of mahogany leaf waste as an alternative pulp raw material for paper production is conducted through a chemical process using different concentrations of NaOH cooking solution and two cooking times, i.e., 120 and 140 min. Mahogany leaf waste is selected as raw material because it is abundant but rarely used. On the basis of the results of this study, we can conclude that the higher the NaOH concentration is, the higher the alpha cellulose pulp content and the lower the pulp yield. Moreover, the cooking time of 20 min does not have a considerable effect on pulp recovery. Mahogany leaf satisfies the requirements for pulp raw materials for papermaking with delignification using chemical processes. On the basis of previous research, for the interest and development of this field, we propose that researchers conduct the advanced stage of delignification, which is bleaching, to obtain pulp for paper with a target kappa number according to the desired product characteristics.

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